eg. an electron, mass 9.11×10^{-31}kg is moving at 0.90c. What is the

a) rest mass energy, in Joules

$E = m_o c^2$

$E = 8.2 \times 10^{-14}$J = 0.50MeV

a) kinetic energy

$E = (\gamma - 1)\, m_o c^2$

$= 1.06 \times 10^{-13}$J

b) total energy

$\gamma\, m_o c^2$

$= 1.87 \times 10^{-13}$J

a) relativistic momentum

$\gamma m_o v$

$= 5.6 \times 10^{-22}$kgm/s = $E_\kappa^2/2m$

V is voltage, or electric potential

electrostatic energy increase = Vq = change in kinetic energy in an accelerator

$E^2 = p^2 c^2 + m_o^2 c^4$

Start with Q 8 and 9

Q8

Δkinetic Energy = ΔVq = 2.5GVxe (charge of proton=e) 2.5GeV

$E = E_k + E_o$ = 2.5GeV + 938MeV

= 2.5+0.938=3.438 GeV
3.438 GeV (1.602x10^{-10}J/GeV)
3.438x1.602=5.5077 =5.5x10^{-10}J

elementary charge, e = 1.602x10^{-19}C

$p=\gamma m_o v$

$E^2=p^2c^2 + m_o^2c^4$

$(3.439\text{GeV})^2 = p^2c^2 + (0.938\text{GeV})^2$
(3.439x3.439)-(0.938x0.938)=10.9469
p= Sqrt(10.9469GeV^2/c^2)=3.308609980036934
p=3.3GeV/c

iii) E_k= can't use $1/2mv^2$ in relativity because mass/length/time effects

$E_k=(\gamma-1)\, m_o c^2$
2.5GeV = $(\gamma-1)$ 0.938GeV
$(\gamma-1)$ = 2.5/0.938=2.6652
γ= 3.6652

3.6652=1/root(1-v^2/c^2)
1/3.6652=0.2728 =
1-v^2/c^2 = 0.2728x0.2728=0.0744
v^2/c^2 = 1-0.0744=0.9256
v = Sqrt(0.9256)=0.962081077664455
v=0.962c

General Relativity:

special relativity = constant velocity

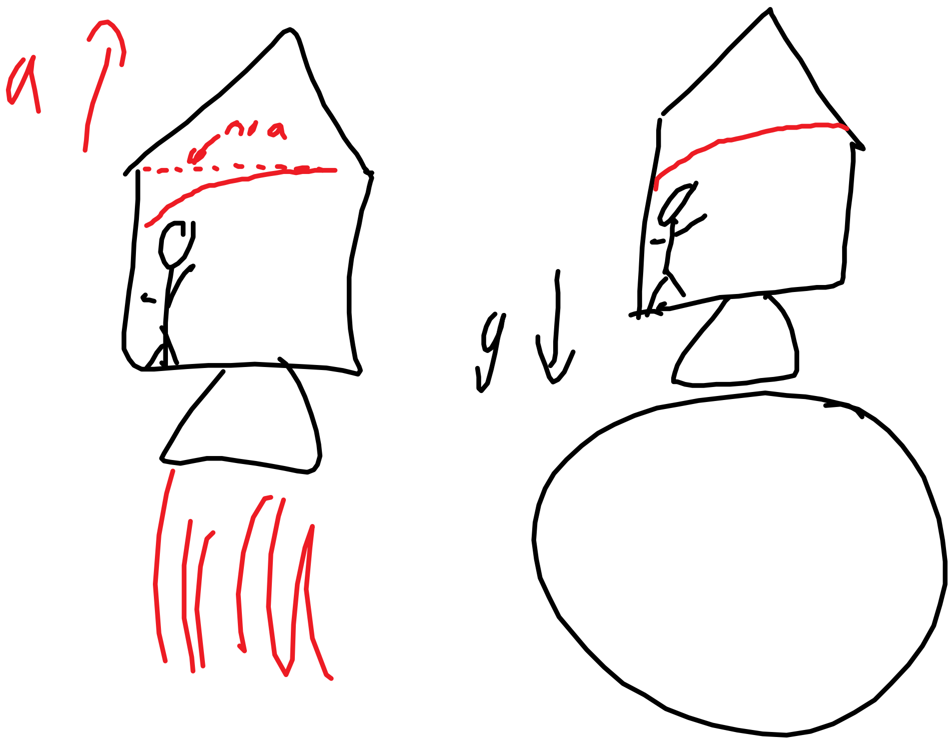
General relativity = acceleration/gravity

Principle of Equivalence:

imaging the classroom windows are closed, how could you tell if you are on Earth or in a spaceship accelerating through deep space at $9.8 m/s^2$?

Einstein - you can't. (other than tidal effects)

Observe a light beam



time is altered by acceleration

Time is affected by
and gravitational effects
↑g slower time relative
to universe (Interstellar)

http://hyperphysics.phy-astr.gsu.edu/HBASE/Relativ/airtim.html#c2

Hafele Keating experiment

Black holes:

Object with a gravitational pull that is large enough that light can't escape.
escape speed = c at the event horizon

usually black holes are formed by big stars collapsing - super large black holes at the centre of galaxies.

Size of the event horizon of a black hole is calculated by the Schwarzschild equation for the Schwarzschild radius.

$R_s=2GM/c^2$

G is the universal gravitational constant, $6.67\text{x}10^{-11}\text{Nm}^2/\text{kg}^2$

M is the mass of the black hole, in kg.
c is the speed of light, 3.00×10^8 m/s

time is warped by the black hole
$\Delta t=\Delta t_o/(\text{root}(1-R_s/r))$
r is the distance to the centre of the black hole
t is the relativist time, r from the centre of the black hole
t_o is the time far from the black hole

next class: red shift -

handout:
Q10, 11